U.S. Regulatory Considerations in the Application of Slurry Fracture Injection for Oil Field Waste Disposal

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Abstract

The principal directive of the Federal Underground Injection Control (UIC) program, authorized by the Safe Drinking Water Act of 1974, is to protect underground sources of drinking water (USDWs) from contamination resulting from the injection of fluids into subsurface geologic formations. The UIC program regulates injection fluids in five classes of wells; Class II wells being for injection of fluids associated with the exploration and production of oil and gas. In 1988 the Environmental Protection Agency issued a regulatory determination stating that E&P wastes, being generally lower in toxicity than other wastes regulated under RCRA, should be exempt from RCRA Subtitle C regulations. Oil field wastes are consequently designated as non-hazardous material under Federal regulations and can be injected into Class II wells. Regulatory oversight for disposal into these wells has been delegated largely to individual States (Primacy States), with the USEPA administering the UIC program in the remaining States (Direct Implementation States).

Disposal of oil field waste into Class II wells through high pressure injection of slurried waste material into deep geologic formations has been successfully implemented in Alaska, the Gulf of Mexico, California, the North Sea, and Canada[1-6]. The method of Slurry Fracture Injection (SFI™) provides an environmentally sound and permanent disposal solution for terminal oilfield wastes where the alternative remedial options of landfills, road spreading, thermal treatment, and separation techniques fall short. Waste injection with this method results in minimal impact to surface land use, and reduced long-term liability to the operator.

Current State regulations generally have some provision for new technologies to be approved. Injection pressures in SFI exceed the formation parting pressures and result in large volumes of waste material being deposited into disposal formations. Although individual State regulations vary, injecting above fracture pressure is often expressly prohibited. At issue is the security of proximal USDWs, and the containment of fractures, and consequently waste material, within the target formation. To minimize the

potential for fracture propagation into confining zones adjacent to USDWs, an acceptable monitoring and analysis program capable of effectively tracking formation response to the SFI process must be designed.

Regulatory acceptance of this oil field waste disposal technique can be achieved through close cooperation between regulatory agencies, waste generators, and the injection project operators. The key to the success is developing sound monitoring strategies which demonstrate fracture orientation and propagation control, and reliably indicate formation response. Evaluating potential strategies to mitigate wastes of higher toxicity in the future may then be considered. Ultimately, protecting human health and the environment through implementation of intelligent remedial options will benefit regulators, operators, and society at large. This paper reviews the Federal framework and State regulations pertaining to high pressure injection of oil field wastes in the oil producing states of California, Alaska, and the Gulf Coast region, and assess future directions of regulatory policy.

1. INTRODUCTION AND BACKGROUND

The generation of non-hazardous oilfield waste (NOW) in oil and gas exploration, development, and production operations results in considerable volumes of material which then must be disposed of in some environmentally sound manner. NOW normally consists of liquid waste such as produced water (brine), production well workover fluids, drilling muds, and tank bottom sludges. Solid waste consists of produced sand, drill cuttings, and in some cases pipe scale.

Deep well injection of oil and gas production waste involves the generation of a pumpable slurry of solid and liquid waste, and subsequent injection of the slurry into a high porosity, high permeability sand formation at depths typically on the order of 4000 to 6000 ft. The depths selected for injection must be well below any potential usable groundwater source. With proper geological formation selection, well design, and a state-of-the-art monitoring program, the injected solids remain entombed in the target formation indefinitely, and will have no adverse effects on groundwater quality.

The general hydrological and geological conditions in oil and gas producing regions such as the onshore and offshore areas of the Gulf of Mexico coastal plain, the north slope of Alaska, and oil productive areas in California, are ideal for the permanent disposal NOW by re-injection into the subsurface. The geology in these areas is well documented and provides for containment of injected waste due to the thickness and lateral extent of target stratum.

Stratigraphic sequences of alternating unconsolidated sand and shale lithologies are characteristic of oil reservoirs and generally have appropriate thickness, porosity, and permeability in the rock matrix for successful fracture injection. Thick unconsolidated sand units become the target injection formation, while overlying shale layers act as a "cap" and provide a permeability barrier to upward fluid migration. Containment of fluids within these zones can be relatively assured, as evidenced by the presence of deposits of oil and gas which remained in place over extended periods of geologic time. Additional sand/shale layers overlying the injection zone provide high permeability sand zones with auxiliary shale caps, which act as a fluid flow sink or buffer zone to ensure isolation of injected materials from overlying formations.

Regulatory control and responsible operation of disposal projects must account for safe waste handling at the surface, placement in the correct strata by the injection process, control over reservoir response with time, and containment of the injected wastes in the target stratum in a safe manner, complying with best environmental practices. In this way, the optimal benefits and value of both favorable economics and environmental security can be realized in waste disposal projects utilizing this technology.

Deep well injection of NOW waste into formations of similar stratigraphy and lithology from whence the produced oil and gas waste material originated, is one of the most environmentally and economically sound disposal options available for these materials. NOW disposal by injection into Class II wells has developed a respectable history of success in the US over the past six years. Successful injection operations in Alaska, the Gulf of Mexico, Texas, California, and Louisiana have contributed to a body of knowledge and data that supports the economic and environmental advantages of this disposal technique[1-4,7-8]. This paper summarizes NOW disposal practices in these regions which utilize deep well injection and addresses the regulatory considerations pertinent to the technology.

2. HISTORICAL FEDERAL AND STATE REGULATORY FRAMEWORK

In the United States, oil and gas is produced from over 800,000 wells across 33 States. During a peak in 1991, over 90,000 wells were drilled in one year[9]. These operations generate large volumes of wastes which are regulated, largely at the State level, by programs consistent with requirements set forth in three major Federal environmental statutes:

- The Safe Drinking Water Act (SDWA), which regulates underground injection activities.
- The Clean Water Act (CWA), which regulates surface discharges.
- The Resource Conservation and Recovery Act (RCRA), which oversees the management and disposal of hazardous and non-hazardous solid wastes.

Wastes associated with the exploration, development, and production of crude oil, natural gas, and geothermal energy were exempted from Federal RCRA requirements in a regulatory determination issued by the U.S. Environmental Protection Agency (USEPA) in 1988[10]. This exemption was based on consideration of the high volumes and relatively low toxicity of E&P wastes, and the potentially adverse economic impact on the petroleum industry if these wastes were regulated as characteristically hazardous wastes[11]. Examples of RCRA exempt wastes include; produced water, drill cuttings and fluids, produced sand, tank bottom and pit sludges, hydrocarbon bearing soils, and pipe scale. Many other wastes associated with hydrocarbon exploration and production, including NORM, were exempted in a subsequent regulatory determination in 1993 (58FR15284)[12].

The Federal SDWA provides for the regulation of underground injection wells used for waste disposal. These provisions establish the Underground Injection Control (UIC) program (see 40 CFR 144-146), which direct the USEPA to prevent contamination of drinking water sources by underground injection and to establish a permit program for such practices. Under a mandate established by the SDWA, the USEPA promulgated regulations which detailed minimum requirements for states to develop and implement UIC programs[13]. The purpose of these programs was to prevent the endangerment of underground sources of drinking water (USDW) by injection wells. USDWs are defined as current or potential sources of drinking water in aquifers which supply any public water system or contain water with less than 10,000 ppm total dissolved solids in sufficient quantity to serve as a public water system[14].

Under the UIC program different classes of injection wells are specified. Class I wells were established for the disposal of hazardous, industrial, and municipal wastes. Class II wells are for the disposal of oil and gas production wastes, for enhanced oil recovery, and for the storage of hydrocarbons. Other special classes of wells were established for the disposal of solution mining wastes, hazardous and radioactive wastes (now prohibited), and wastes not covered under any other category.

For the purposes of this discussion, we will focus largely on regulations governing Class II disposal wells, with a brief discussion of potential uses of deep well fracture injection for hazardous wastes into Class I wells.

3. PERMITTING AND REGULATORY ISSUES SPECIFIC TO NOW WASTE DISPOSAL

In the absence of Federal regulations, State provisions prevail in the handling and disposal of non-hazardous oil field wastes. Regulatory oversight for disposal into Class II wells has been delegated by the USEPA largely to individual States (Primacy States), with the USEPA administering the UIC program in the remaining States (Direct Implementation States). Appendix A lists the Primacy and Direct Implementation States. In Federal waters, the Minerals Management Service (MMS) and the US Coast Guard (under the Federal Division of Transportation) oversee regulatory issues.

High rate injection of blended (slurrified) solid and liquid oil field waste requires the material to be injected at or slightly above the parting pressure of the formation. Under 40 CFR 144, Class II well permits for injection of non-hazardous wastes must establish maximum injection volumes and/or pressures necessary to assure that fractures are not initiated into the confining zones, that injected fluids do not migrate into any USDW, and that formation fluids are not displaced into any USDW. The critical criterion being that confinement within the target formation can be assessed and controlled. Many State regulations stipulate that pressure in the injection zone during injection may not initiate new fractures or propagate existing fractures within the injection zone itself. As a result, waivers of this condition must be acquired prior to permitting in these states, or the project may be designated a demonstration project using a new technology.

Offshore Gulf of Mexico

Historically, produced NOW in the Gulf of Mexico outer continental shelf has been primarily disposed of by discarding the material overboard of the drilling platform. The regulatory environment changed this practice in January, 1997 when the Gulf coastal zone was designated as a zero discharge zone. This means that offshore platforms may no longer dispose of drilling wastes into the sea and are instead compelled to transport much of this material onshore. Alternative disposal methods for these produced well solids include annular injection, deep well injection, and landfill application.

Due to the increased regulation and restrictions on overboard discharge, several operators switched to the more environmentally appropriate practice of re-injection of produced wastes to the subsurface[2]. Most of these offshore disposal operations involve relatively low volume injections, often reinjecting only the material produced from the drilling of that particular well.

Alaska

The USEPA maintains primary responsibility for the administration of various federal environmental programs in Alaska including the UIC program, but their jurisdiction excludes Class II wells in the state. The Alaska Oil and Gas Conservation Commission (AOGCC) has primacy for these Class II UIC wells. The AOGCC permits the disposal of Class II fluids into dedicated oil field waste disposal wells under Alaska Administrative Code 20 ACC 25.252.

Texas

Oil and gas activities in Texas are regulated by the Railroad Commission of Texas (TRC). It is responsible for the prevention of both waste and pollution, and most aspects of environmental protection. Requirements for Class II disposal wells are found in Rule 9 of the Texas Administrative Code (TAC). Rule 9 also stipulates construction details, testing and operating requirements, and maximum injection pressures. Currently, there is no provision in the TAC for injecting slurried solid and liquid wastes above fracturing pressures into subsurface formations. The TRC has, however, expressed support for a pilot-scale project to test the deep well injection technology on a case-by-case basis[15].

Louisiana

In Louisiana the oversight of all onsite Class II NOW injection projects is the responsibility of the Office of Conservation (OC). The OC has regulatory authority for oil and gas waste in the state, and oversees all oil and gas disposal wells. The Louisiana Department of Environmental Quality (DEQ) regulates the National Pollutant Discharge

Elimination System (NPDES) program which covers surface discharges of NOW and other waste. Annular disposal of drilling and workover wastes is allowed, and over two thirds of produced water is reinjected into the producing formation[16]. Provisions contained in Statewide Order 29 cover Injection and Mining under Title 43 of the Natural Resources code, Part 17 for Louisiana.

In 1997 Louisiana permitted the first onshore fracture injection project for NORM to Chevron USA Production Company who began injecting NOW and NORM derived from oil production operations. The disposal of NORM into either a commercial or noncommercial Class II well in Louisiana requires both a license from the DEQ, and a Class II permit from Department of Natural Resources.

California

As a Primacy State, California's Division of Oil, Gas and Geothermal Resources (DOGGR) has jurisdiction over the UIC program and issues permits for Class II injection wells in the state, although the State Water Quality Control Board retains final approval authority over DOGGR permits.

In concurrence with a DOGGR determination made in early 1996, the USEPA Region 9 classified crude-oil-saturated surface soil as a Class II waste. This conclusion was based on the following; (1) injection of this material into a depleted, oil-saturated reservoir was the best possible form of remediation, (2) hydrocarbon-bearing soils are a non-hazardous exploration and production waste exempted from RCRA Subtitle C regulations, (3) the proposed injectate is integrally and uniquely associated with E&P operations, and (4) USEPA Region 6 had already issued a clarification to the Louisiana Office of Conservation stating that all E&P RCRA exempt wastes, which include hydrocarbon-bearing soils and pit sludges, are eligible for injection into Class II disposal wells.

These findings cleared the way for approval of the first permitted application of deep well fracture injection for remediation of crude contaminated surface soils in California[3] in the summer of 1997. The fracture containment provisions detailed in 40 CFR 144, and an extensive monitoring program to verify containment of material within the target formation, were stipulated in the permit.

4. DISCUSSION

There have been recent developments in the use of deep well fracture injection for disposal of other fluids associated with oil and gas production. In these cases, the Class II designation is not appropriate since all of the waste may not have originated down hole. Class I non-hazardous wells have been proposed for use in this manner. Historically, fracturing into a Class I well has been prohibited (40 CFR 146). However, in a recent application from the Beaufort Sea off the North Slope of Alaska, the use of a Class I well to dispose of industrial waste from an offshore rig by fracture injection has been supported by the USEPA Region 10 office. In this case, the waste is

largely classified as E&P waste which may be injected into either a Class II well or a Class I well. The waste stream in this case, however, includes wastewater from rig operations which may not be injected into a Class II well. For this reason, a Class I well must be utilized for injection.

In another important potential application of this technology, a public notice was recently issued in Texas which included deep well injection as a remedial alternative in a Superfund cleanup of waste including hazardous material. In this instance, deep well injection presents an option which provides more effective protection for human health and the environment than the alternatives[17].

A formal regulatory framework has yet to be developed specifically for deep well fracture injection disposal. A positive trend towards permitting this technology on a case-by-case basis in most areas should lead to wider awareness and support in the regulatory community. Continued successful precedents of economic and environmental dividends from the implementation of this technology may also fuel further market demand.

Developing regulations should remain flexible yet comprehensive in order to adequately address the operational challenges of this technology, while achieving the regulatory goals of human health and environmental security.

The ultimate purpose behind establishment of a formalized regulatory framework for deep well fracture injection is to meet the following goals:

- Eliminate any risk of impairment of present or future resources (oil, gas, potable water, minerals);
- Minimize any risks of the solid wastes, any liquid slurry phase, or any potential future leachate from interacting now or in the future with shallow groundwater or the biosphere;
- Maximize personnel safety in handling the waste material on the SFI site.

Keeping these goals in mind, one can design an injection facility and dispose of the waste using best possible practices. Careful supervision by and interaction with the regulatory agencies involved in past and current operations has proven mutually beneficial. A cooperative, constructive relationship has evolved between the fracture injection operators and the regulators, working together towards the regulatory agencies' goals regarding the disposal of the permitted waste streams, and the operators' goals of successfully disposing of oilfield waste material in a timely, economic fashion[18].

REFERENCES

1. Louviere, R.J., and Reddoch, J.A., Onsite disposal of rig-generated waste via slurrification and annular injection. SPE/IADC #25755 (1993).
2. Rutherford, G. J., and Richardson, G. E.,1993, Disposal of Naturally Occurring Radioactive Material From Operations on Federal Leases in the Gulf of Mexico, SPE 25940, presented at the SPE/USEPA Exploration & Production Conference, San Antonio, TX 7-10, March.
3. Sipple-Srinivasan, M.M., Bruno, M.S., Hejl, K.A., Danyluk, P.G., and Olmstead, S.E., Disposal of crude contaminated soil through slurry fracture injection at the West Coyote Field in California, SPE 46239, Proc. West. Reg. Mtg. SPE, Bakersfield, CA, May 10-13, 1998.
4. Malachosky, E., Shannon, B.E., and Jackson, J.E., Offshore disposal of oil-based drilling fluid waste: An environmentally acceptable solution. SPE #23373 (1991).
5. Schuh, P.R., Secoy, B.W., and Sorrie, E., Case history: Cuttings reinjection on the Murdoch Development Project in the southern sector of the North Sea. SPE #26680 (1993)
6. Dusseault, M.B., Bilak, R.A., and Rodwell, G.L., Disposal of Dirty Liquids using slurry fracture injection. SPE 37907, (1997).
7. Hainey, B.W., Keck, R.G., Smith, M.B., Lynch, K.W., and Barth, J.W. On-site fracturing disposal of oilfield waste solids in Wilmington Field, Long Beach Unit, CA. SPE #38255 (1997).
8. Marinello, S.A., Ballantine, W.T., and Lyon, F.L. Nonhazardous oil field waste disposal into subpressured zones. Environmental Geosciences, 3, 4 (1996), 199-203.
9. U.S. Environmental Protection Agency, 1993, "Clarification of the Regulatory Determination for Waste from the Exploration, Development and Production of Crude Oil, Natural Gas, and Geothermal Energy." 58 Federal Register, pages 15284-15287, March 22.
10. U.S. Environmental Protection Agency, 1988, "Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes." 53 Federal Register, pages 25446-25459, July 6.
11. U.S. Department of Energy Office of Fossil Energy, Interstate Oil and Gas Compact Commission, 1993. "Oil and Gas Exploration and Production Waste Management: A 17-State Study."
12. Veil, J. A., Smith, K. P., Tomasko, D., Elcock, D., Blunt, D. L., and Williams, G. P., 1998, Disposal of NORM-Contaminated Oil Field Waste in Salt Caverns, August 1998, Argonne National Laboratory.
13. Elliott, J.F., Henderson, M.A., Weinsoff, D.J., Polkabla, M.A., Demes, J.L., 1994, *The Complete Guide to Hazardous Materials Enforcement and Liability*, prepared by Touchstone Environmental, Inc., Oakland, California.
14. Brasier, F.M., and Kobelski, B.J., 1996, Injection of Industrial Wastes in the United States, in *Deep Injection Disposal of Hazardous and Industrial Waste: Scientific and Engineering Aspects*, Academic Press, pp 1-8.

15. DeLeon, F., 1997, personal communication between DeLeon, Railroad Commission of Texas, Austin, TX, and M. Srinivasan, Terralog Technologies USA, Inc., Arcadia, CA, October 8.

16. U.S. Environmental Protection Agency/IOCC, 1990, Study of State Regulation of Oil and Gas Exploration and Production Waste, December.

17. CH2MHill, Inc., 1998, Tex-Tin Superfund Site, OU No. 1 Feasibility Study Report prepared for U.S. Environmental Protection Agency, Response Action Contract No. 68-W6-0036, March

18. Dusseault, M.B., Danyluk, P.G., Bilak, R.A., 1998, Mitigation of Heavy Oil Production Environmental Impact Through Slurry Fracture Injection, paper prepared for presentation at the Seventh UNITAR International Conference on Heavy Crude and Tar Sands, Beijing, China, October 27-30.

Appendix A

Class II underground injection control (UIC) programs are administered directly by the states through primacy delegated by the USEPA in states which have applied for and received the Primacy State designation. The UIC Class II programs are administered directly through the USEPA in states that have not sought or obtained primacy for the UIC program. These states are designated as Direct Implementation States. The following is a list of Primacy and Direct Implementation States for Class II wells in the 34 primary oil and gas producing states as of a 1990 survey conducted by the Interstate Oil Compact Commission (USEPA/IOCC, 1990).

Primacy States	**Direct Implementation States**
Alaska	Arizona
Alabama	Florida
Arkansas	Kentucky
California	Michigan
Colorado	Montana
Illinois	New York
Indiana	Pennsylvania
Kansas	Tennessee
Louisiana	Virginia
Maryland	
Mississippi	
Missouri	
Nebraska	
Nevada	
New Mexico	
North Carolina	
North Dakota	
Ohio	
Oklahoma	
Oregon	
South Dakota	
Texas	
Utah	
West Virginia	
Wyoming	